Section III: Introduction

This Section of the *Field Guide* focuses on further reducing the home's energy demand by optimizing the systems and equipment typically used to operate the household. The goal is to select energy efficient equipment and to utilize natural sources of energy (sunlight) as much as possible. To do this successfully, it is important to:

1. Implement the design techniques described in Section II as appropriate.
2. Use the information in this section to integrate system and appliance choices into the design process for:

    - Water Heating (Chapter 13)
    - Lighting (Chapters 14 and 15)
    - Appliances (Chapter 16)
    - Air Conditioning (Chapter 17)

A summary of key strategies and recommended techniques from Chapters 13 through 17 is provided at the end of this section, on page 88.

Chapter 13: Water Heating

Water heating typically accounts for up to 40% of utility bills in non-air conditioned homes. Strategies to reduce energy used for water heating include:

- Solar water heating
- Water-conserving fixtures and appliances
- Properly sized, high performance equipment
- Proper maintenance and operation.

Recommended Technique: Install solar water heating.

Choosing a solar water heater over a conventional water heater can reduce water heating costs by 80% to 90%. Table 13-A compares energy use among water heating types.

Table 13-A: Comparison of Energy Use for Water Heaters

Type of Water Heater	How it Operates	Recommended Energy Efficiency Standard	Savings Compared to Conventional Electric Resistance Water Heater
Solar Water Heater	Uses the warmth of sunlight to heat water.	Highly efficient so no rating is necessary.	80-90%
Heat Pump	Removes heat from surrounding air and transfers it to a water tank.	COP* of 2.7 or higher.	65%
Gas	Uses a flame powered by natural gas to heat the water.	EF** of 0.60 or higher.	Typically some savings, but dependent on the variable cost of natural gas and electricity.
Electric Resistance	Uses an electric element to heat the water.	EF** of 0.88 or higher (value depends on tank size).	Typically the most expensive type of water heater to operate.

* COP (*Coefficient of Performance*) is the rate of heat delivered divided by the energy needed to run the heat pump.

** The EF (*Energy Factor*) measures how well the heater retains heat. The higher the EF, the more efficient it is.

With current state income tax credits and utility rebate programs, the cost of a new solar water heating system is paid back through utility bill savings in less than four years. For more details on the benefits of solar water heating, see Chapter 19.

Since solar water heating is the most energy efficient choice, anything a builder does to facilitate its installation now or later in the home is encouraged. If installing a solar water heating system is not possible initially, there are ways you can make a future installation more cost effective, such as providing water line stub outs to the roof and providing hot water tanks suitable for a solar hot water system. Builders can also offer a “pre-solar” package by providing the stub out and no tank, allowing the home owners to hire a contractor themselves to install the solar hot water system later. Check with your local electric utility company for rebates and contractor recommendations.

Recommended Technique: Install water-conserving fixtures and appliances.

When you decrease the amount of hot water used in the home, you reduce the amount of energy used to heat the water. Aerators in faucets and low-flow showerheads can cut hot water requirements by 50%. Install bathroom faucets that use no more than 2 gallons per minute (gpm). Other sink faucets and showerheads should use no more than 2.5 gpm.

Running full loads and using water conserving dishwashers and clothes washers provide more opportunities for savings. See Chapter 16, for more details.

Recommended Technique: Select high efficiency equipment.

For heat pump, gas, or electric water heaters, select high efficiency equipment. See Table 13-A for recommended efficiency levels and Appendix G for the utility rebate plans.

Recommended Technique: Properly size water heating equipment.

To properly size the equipment, first estimate the household's hot water requirements. Generally, a four-person household in Hawaii uses about 80 gallons of hot water per day. Energy performance is best when the system is sized to meet 110% of the household's projected demand. (Source: DBEDT "A Home Owner's Guide to Solar Water Heating," March 2000)

Recommended Technique: Provide for efficient operation and maintenance.

Techniques for achieving additional efficiencies include:

- Control heat loss through pipes delivering hot water by wrapping pipes with a diameter up to 2 inches with insulation of R-4 or greater. Pipes with a diameter of more than 2 inches should be covered with insulation of R-6 or greater.
- Adjust the water heater's thermostat to 120ºF.
- Install a heat trap in the water heater lines. A heat trap is a piping arrangement that prevents hot water from rising up in the pipes, thereby reducing heat losses.
- For electric water heaters, install a timer that can automatically turn the water heater off at night and on in the morning. A simple timer can pay for itself in less than a year. OR, enroll in a demand control program through the local electric utility. The program will require larger storage capacity tanks and timers to limit heating hours to night time.
- Provide owners with information about proper maintenance procedures. Proper maintenance can prevent tank sediments from building up, which reduces efficiency. For details, see Appendix E.
- If installing a solar water heating system, refer to "Solar Standards and Specifications, April 1, 2000, List" for pre-approved equipment from Hawaiian Electric Company, Hawaii Electric Light Company, or Maui Electric Company.

Chapter 14: Daylighting

People prefer natural light to artificial light because it connects us to the outdoors and natural rhythms. In addition, daylight can provide ambient illumination reducing electrical lighting needs. Thus, "daylighting" makes a home more livable and pleasant and can save on utility bills.

Natural light, however, can be difficult to control. Misapplied, it can produce excessive heat gain, uncomfortable glare, and degradation of furniture and finishes. If building orientation is ignored and window and door openings are designed without regard to the distribution of daylight, the result can be a home with blinds drawn to block excessive daylight, with electric lights on during the day.

This chapter covers strategies that prevent direct light from entering the home while optimizing distribution of daylight. Techniques include:

- Minimizing difficult-to-shade east- and west-facing windows
- Interior layouts that match lighting needs to daylight availability
- Improved interior distribution through light-colored finishes
- Floor plans that allow deep daylight penetration
- Light shelves for sidelighting
- Clerestories or roof monitors for toplighting
- Minimizing heat gain and glare when using skylights

Combining daylighting strategies effectively with strategies covered in Chapter 15 will provide maximum energy savings and visual comfort. Coordinate your choice of daylighting techniques with other passive design strategies such as natural ventilation and shading. See Chapter 10.

Daylighting Methods

Two effective methods for allowing daylight into the home are sidelighting and toplighting. *Sidelighting*, as the name implies, is achieved through openings in the side of a building. *Toplighting* is accomplished through openings in the roof. See Figure 14-1.

Clerestories, roof monitors, and skylights are examples of toplighting. *Clerestories* are vertical openings located high in the wall. *Roof monitors* are vertical glazed openings located in the roof or in the roof plane. Because they are vertical, they are easier to shade and much less likely than skylights to produce excessive heat gain. Typically, clerestories have fixed glazing, and roof monitors have operable glazing. Thus, roof monitors can assist natural ventilation while providing daylighting.

Skylights in Hawaii should be used sparingly and designed to minimize heat gain and glare. Even when heat gain through skylights may be beneficial, such as in homes located at cooler elevations above 2,500 ft., glare can still be a problem.

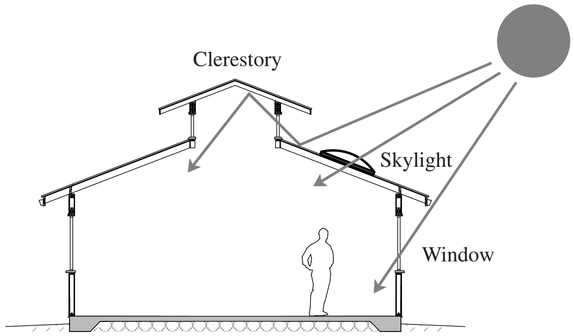


Fig. 14-1: Daylighting Methods.

Windows provide sidelighting. Clerestories, roof monitors, and skylights provide toplighting.

Daylight Distribution

The secret to designing with natural light is distribution. The goal is to bring light in where it is desired while avoiding excessive contrasts, glare, unwanted heat gain, and high light levels. To use the sun's light comfortably, sunlight should be reflected and diffused deep into interior spaces.

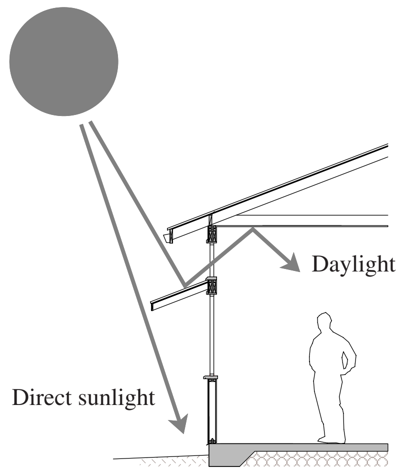


Fig 14-2: Distribution of Daylight.

Daylight is indirect light (ambient or reflected). Direct sunlight should not be allowed to enter the home's interior.

Recommended Technique: Minimize difficult-to-shade east- and west- facing windows.

The exterior building envelope should be designed to admit indirect light through the windows or the roof. Be careful to minimize east- and west-facing windows, which are difficult to shade and may admit unwanted heat and glare. See Chapter 10 for additional details on window placement and shading techniques.

Recommended Technique: Design interior layouts to match lighting needs to daylight availability.

The building's interior design should provide daylight where it is most needed. Activities with higher illumination needs should be placed along the home's perimeter where access to natural light will be greatest. Activities with lower lighting demands can be located deeper inside.

Although light coming from the north or south generally provides a more even level of lighting, client preference may require a customized approach. For example, "morning people" may prefer to have the bedroom, bathroom, and kitchen facing east so they can enjoy the morning sun. Others may prefer a darker bedroom in the morning and brighter living spaces in the afternoon/evening for late-day activities.

Recommended Technique: Use light-colored interior finishes.

The color of interior finishes can greatly affect light distribution. Light-colored, glossy surfaces reflect more light than dark or matte surfaces and improve overall light distribution in a space. Typically the color of the ceiling and walls has the greatest impact on light distribution. Floor color can affect light quality, but not as significantly.

Although light-colored glossy surfaces reflect more light, they must be used judiciously in order to avoid glare. Light-colored matte surfaces reflect and diffuse light, creating a more controlled and evenly lit environment.

Recommended Technique: Design floor plans to allow deep daylight penetration.

Daylight penetration depends on the proportions of the interior space and the size, number, and location of openings that bring light into the space. For example, the back of a large, deep room with one small window will not receive much light. Interior penetration of daylight is most effectively achieved with high ceilings and a narrow building plan with openings on several sides. Open floor plans with few interior partitions also allow deeper light penetration. Single-story buildings are generally easier to daylight than multi-story structures because roof openings can be used to bring light into deep spaces. The proportions of a room also have a significant impact on the distribution of the light. Higher ceilings allow deeper light penetration.

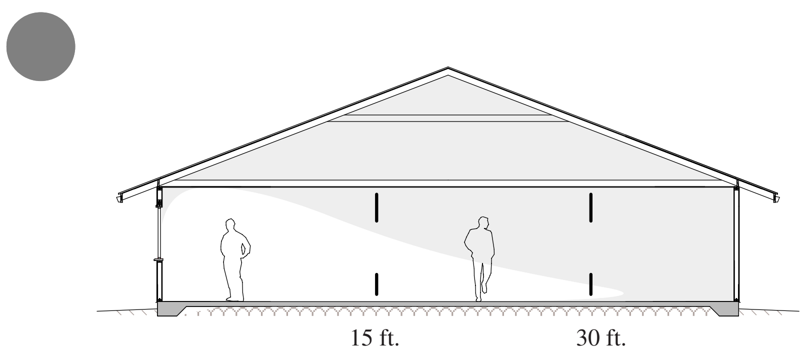


Fig. 14-3: Daylight Penetration.

With an 8 ft. ceiling, daylight is typically sufficient for normal activities 15 ft. into the space. Between 15 ft. and 30 ft. from the window, some electrical light will be needed to augment the daylight. More than 30 ft. from the window, electrical light will supply most of the illumination.

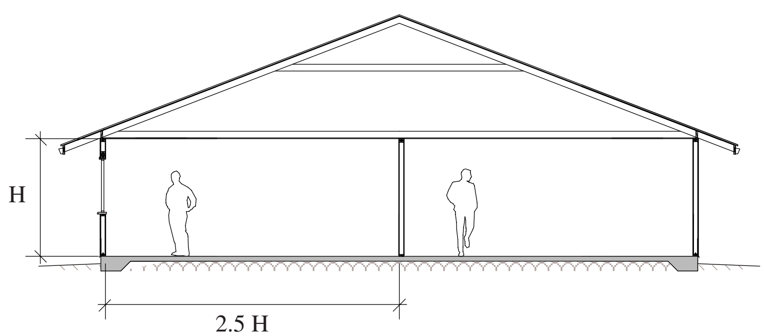


Fig. 14-4: Room Proportions and Daylight Penetration.

For a single sidelit room, the depth of the room should be no greater than 2.5 times the height of the wall with the opening(s).

Recommended Technique: Use light shelves when sidelighting.

A light shelf is a horizontal reflector used to direct light into the interior of a building.

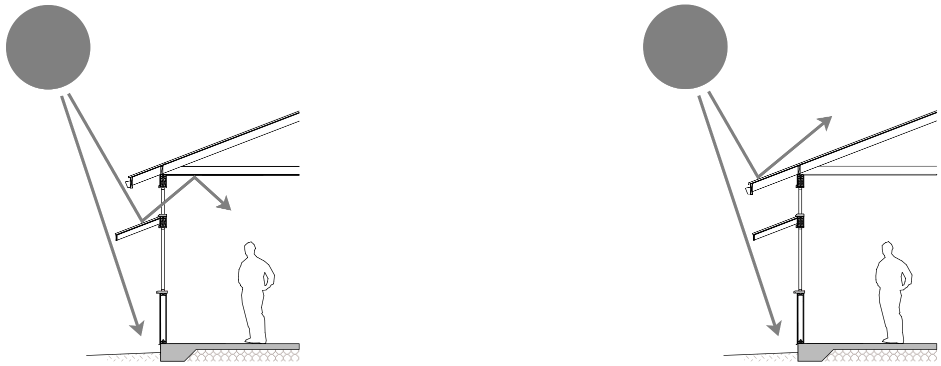


Fig. 14-5: Use Light Shelves when Sidelighting.

A light shelf can provide shading and indirect light when sidelighting. When placed between windows, it prevents heat gain through the lower window and reflects light through the upper one.

Locations and placement of light shelves must be carefully dimensioned with roof overhangs. Poorly coordinated light shelf and overhang relationships can reduce the benefits of the light shelf.

Recommended Technique: Use clerestories or roof monitors for toplighting.

Clerestories and monitors can be located independently of walls, so they can be placed where daylight is needed. They can be very small while delivering effective illumination. Shading design for clerestories and monitors is the same as for standard windows. For more information on proper shading design see Chapter 10.

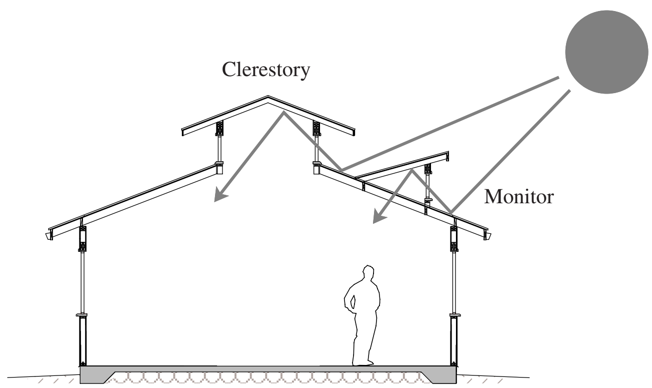


Fig. 14-6: Use Clerestories or Roof Monitors for Toplighting.

Clerestories and monitors are easier to shade and admit less heat than skylights.

Recommended Technique: Minimize heat gain and glare when installing skylights.

Hawaii's tropical latitude of 19° to 22° north exposes roofs to intense sunlight. As a result, skylights can cause excessive heat gain and glare. Avoid overheating by selecting the appropriate glazing and by limiting the size of unshaded skylights.

When selecting skylight glazing, look for a solar heat gain co-efficient (SHGC) of 0.5 or less. The SHGC measures the amount of solar radiation admitted through the window. For more information on glazing attributes, see Chapter 10.

Operable and vented skylights help offset heat gain by venting hot air. Venting skylights should be placed on the leeward side of the house to facilitate venting. If the openings are placed on the windward side, the incoming air can trap hot air in the building. If the vents are fixed open, they must be shielded from rain infiltration. If vents are operable and exposed, they must be closed like any window to prevent water penetration.

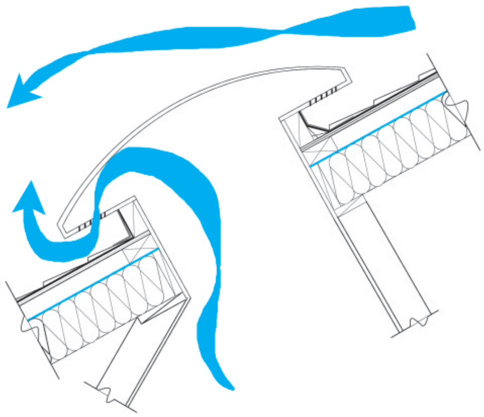
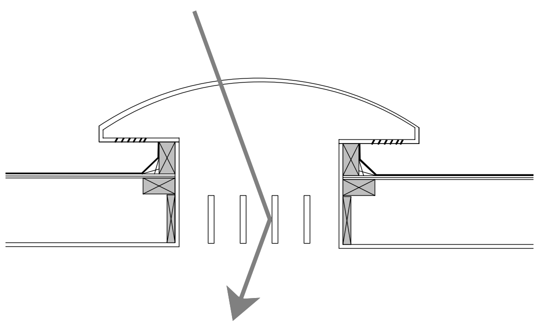


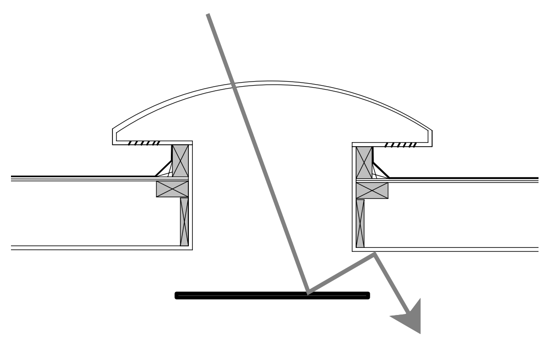
Fig. 14-7: Use Vented Skylights to Offset Heat Gain.

A built-in vent can help offset heat gain caused by skylights. The venting skylight should be installed on the leeward side of the house so breezes can help draw hot air out of the home.

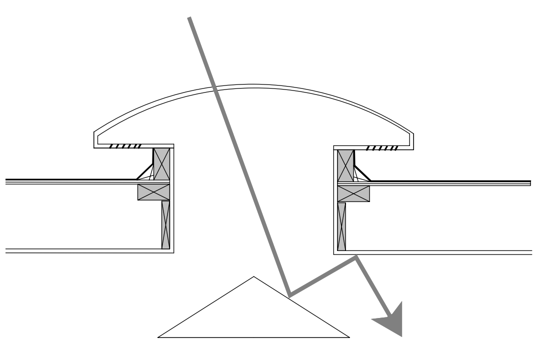
Unshaded skylights admit direct sunlight into a home. Skylights that incorporate translucent materials, such as white plastic, diffuse the incoming light and help reduce glare. Another way to reduce glare is to diffuse or reflect the light with a baffle that is placed below the ceiling plane (see Figure 14-8 below).



Vertical baffle.



Horizontal baffle.



Angled baffle.

Fig. 14-8: Light Baffles Reduce Glare by Diffusing and Directing Incoming Sunlight.

Brightness contrasts can be reduced by locating the skylight next to a wall, which will receive and distribute the light, or by sloping the ceiling up to the skylight ("splaying," see Figure 14-9).

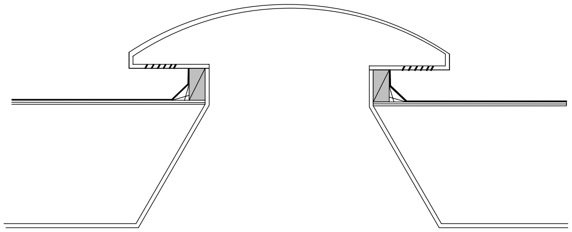


Fig. 14-9: Toplight Distribution.

Splaying is another way to distribute toplight. Brightness contrasts can be reduced by sloping the ceiling up to the skylight.

High ceilings will also improve light distribution. These specific recommendations address light quality, not heat gain.

Chapter 15: Electric Lighting

In Hawaii, 8% of the average household electric bill is for electric lighting. Unfortunately, most of this energy goes into powering inefficient incandescent bulbs. Only 10% of the energy used by incandescent bulbs produces light; the other 90% is wasted as heat. Switching from incandescent to fluorescent bulbs in key locations can save energy and money while reducing an interior source of heat build-up.

A well-considered lighting design can significantly reduce the energy used for lighting. Efficient lighting design ensures that the right amount and the right type of light gets to where it is needed. Efficient lighting avoids overlighting and incorporates daylighting. (For daylighting strategies, see Chapter 14).

Lighting design can be highly complex. This *Field Guide* provides only an overview of key concepts needed to understand the rationale for the strategies presented. It is not intended to be a comprehensive lighting design guide. Please refer to the resources listed in Appendix B for in-depth coverage of lighting design principles.

Strategies presented in this Chapter include:

- Effective electric light delivery
- Fluorescent bulbs

The following is a brief glossary of useful terms to assist you as you read this chapter:

- *Lamp:* A generic term used for a manufactured item that produces light (light bulb). In this chapter, the more common term *"bulb"* will be used, rather than the term "lamp."
- *Incandescent lamp:* A lamp that produces light by heating a wire with electricity.
- *Fluorescent lamp:* A lamp that contains an inert gas and produces light by exposing its internal coating to UV radiation.
- *Ballast:* A device used with fluorescent lamps to establish the circuit conditions necessary to start and operate the lamp.
- *Fixture* or *luminaire:* A lighting fixture. In this chapter, "fixture" will be used when referring to the bulb and the housing that holds it.
- *Lumen:* A measure of the amount of light given off by a light source.
- *Efficacy:* A bulb's efficiency expressed in lumens per watt (lum/W). In this chapter, the more commonly understood term "efficiency" will be used.
- *Footcandle (fc):* A measure of the amount of light that actually reaches a surface.
- *Watt:* A measure of energy. The wattage on bulbs shows how much power is being drawn to create the light—*not* how much light is produced.
- *Color Rendering Index (CRI):* The CRI measures how "natural" colored objects appear when illuminated by a bulb. The higher the CRI, the truer the color of the objects being lighted. The CRI ranges from 0 to 100.
- *Correlated Color Temperature (CCT):* The CCT measures the appearance of the light itself. Light with a low CCT (below 3100K) looks warm while light with a high CCT (above 4000K) looks cool; those in between appear neutral, neither warm nor cool. A soft white incandescent bulb has a CCT of 2800.

Recommended Technique: Design for effective electric light delivery.

Efficient lighting design delivers the right quantity and quality of light where it is needed. The first step then is to determine how much electric light is needed to augment daylighting and what quality of light is needed. This will depend on what kinds of activities will be happening in a given location. Generally speaking, the more complex a task, the more light is needed to perform it. In addition, the more detailed the task, the more focused the light should be that illuminates it.

Distribution

You may recall from the discussion of daylighting in Chapter 14 that the key to good lighting design is getting the right distribution. There are three lighting styles: ambient or general, task, and accent. These styles offer specific distribution types: direct, indirect, direct-indirect, and diffuse (spread out), which are achieved through a variety of fixture designs. Table 15A matches lighting style to distribution type and purpose. Figures 15-1 through 15-4 provide examples of lighting methods.

Fixtures (Luminaires)

As seen in Table 15-A, ambient light can be provided by more than one distribution type. Different distributions are achieved by varying the type, size, and location of fixtures. For example, suspended, architectural, wall, and some portable fixtures, such as table, desk, or floor lamps, can provide soft, indirect light that eliminates shadows or dark gloomy ceilings. Globe fixtures, chandeliers, and some portable lamps can provide diffused light, or light that is spread out equally in all directions. To achieve these effects without uncomfortable glare, fixtures will include design features that shield, redirect, or diffuse the light. (Glare can also be avoided by adequate illumination of surrounding surfaces.)

Table 15-A: Lighting Styles

Lighting Style	Distribution Types	Appropriate for:
Ambient (general) provides uniform illumination for a whole room. Amount of light will depend on the reflectance of surfaces in the room. See Figures 15-1 and 15-2.	• Indirect • Direct-Indirect • Diffuse • Direct	Simple activities, such as watching TV, dining, or casual reading.
Task directs light to a specific area. See Figure 15-3.	• Direct • Direct-Indirect	Detailed tasks, such as reading or working in the kitchen. Using focused, task lighting rather than ambient lighting can save energy.
Accent is focused, similar to task lighting, but highlights features rather illuminates an activity. See Figure 15-4.	• Direct	Highlighting art or architectural features.

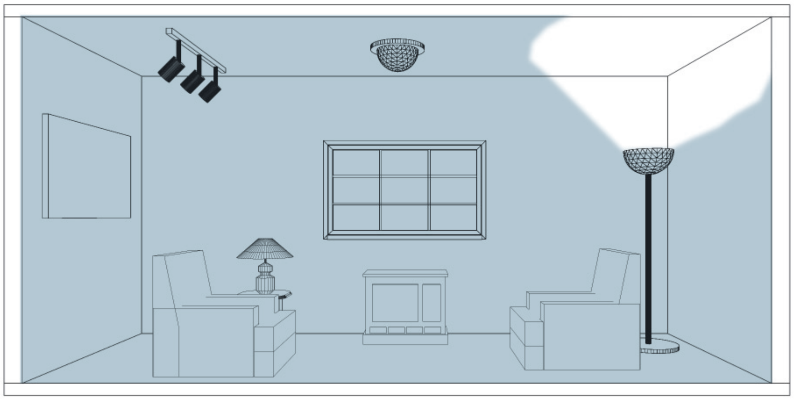


Fig. 15-1: Indirect, Ambient Lighting.

Light reflects off a surface (typically the ceiling) to illuminate the room.

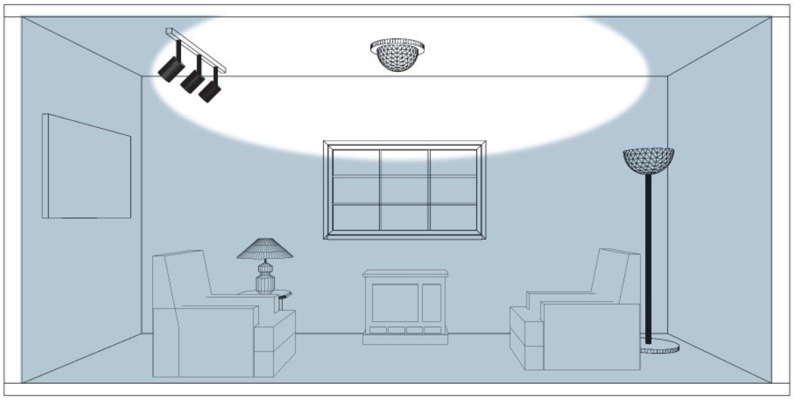


Fig. 15-2: Diffuse, Ambient Lighting.

Light is distributed uniformly in all directions through a diffusing globe (usually a white glass) that encases the bulb. For minimal glare, the globe should be large and the bulb wattage should be low.

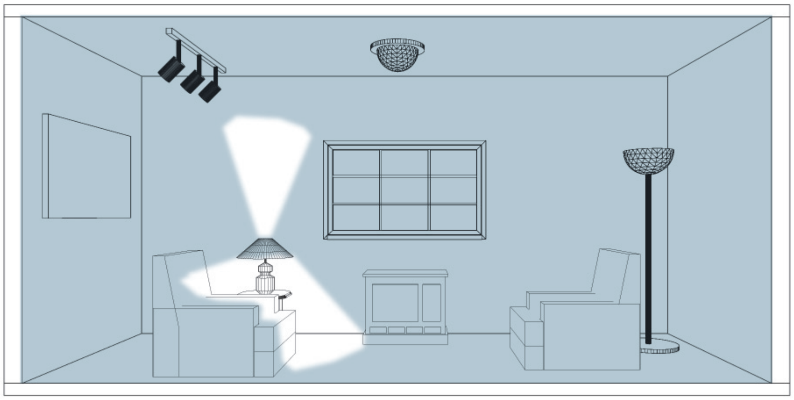


Fig. 15-3: Direct-Indirect Lighting.

The light source directs light upward and downward. Some fixtures provide some light to the side. This type of lighting provides a good compromise between the efficiency of direct lighting and the comfort of indirect lighting.

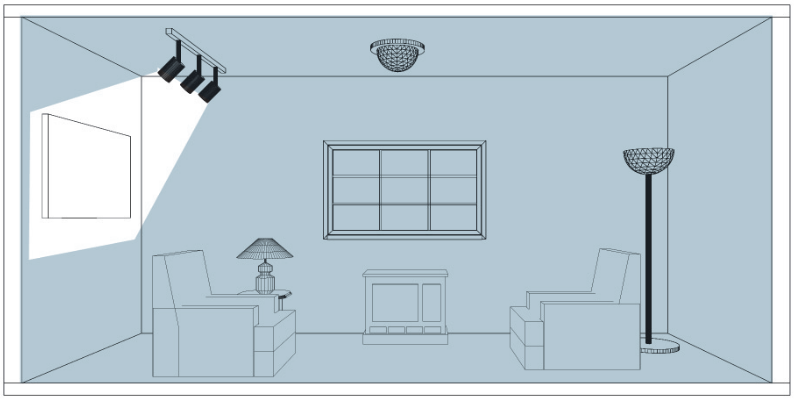


Fig. 15-4: Direct Lighting.

The fixture aims the light directly at a surface. In the example, the purpose is for accent lighting, but can also be used for task lighting.

Bulbs (Lamps)

In choosing a bulb type for a particular lighting application, evaluate its efficiency expressed in lumens per watt, color rendering ability (CRI), and color appearance (CCT).

Efficiency (Efficacy)

Efficiency (expressed in lumens per watts) is a more important characteristic than wattage to use in selecting bulbs. It is similar to comparing fuel efficiency for cars. Cars that can travel more miles per gallon use less fuel to operate. In the same way, bulbs that use fewer watts to produce the same amount of light are more efficient. For example, an 18-watt compact fluorescent bulb produces approximately the same amount of light as a 60-watt incandescent bulb. Thus it is several times more efficient and has a higher lumen/watt ratio.

Color Rendering

The importance of color rendering will vary from room to room. Remember, the higher the CRI, the more natural objects will appear. A CRI of 80 or higher will be satisfactory for most applications. Modern fluorescent bulbs are available with CRIs of 80 and above. Lighting in a bathroom may require bulbs with CRIs of 90, since color rendering may be more critical in these areas.

Color Appearance

Largely a matter of personal preference, the color appearance of bulbs is measured by their CCTs. Home owners with a preference for a warm look will prefer bulbs with CCTs of 3000K or less. There are now fluorescent bulbs that meet this criteria. Neutral color appearance can be obtained with bulbs that have CCTs of 3500-4000K, and for a truly cool appearance, use CCTs above 4000K. See table 15-C for CCT values by bulb type.

Bulbs are labeled with a code that identifies bulb type, CRI, and CCT. For example a fluorescent bulb labeled RE730 means that the bulb is a rare-earth-phosphor bulb (the high-quality phosphors achieve higher efficiency and excellent color rendering) with a CRI in the 70s and a CCT of 3000K.

Ballasts

Fluorescent bulbs require ballasts to operate. *Ballasts* are devices that control the voltage needed to start the bulb and the current required during bulb operation. A ballast may operate one or more bulbs. There are two types of ballasts, magnetic and electronic. *Electronic ballasts* are preferred because they operate at much higher frequencies (20,000 Hz) than *magnetic ballasts* (60 Hz). This higher frequency results in a 10% to 12% increase in bulb efficiency and eliminates the perceptible flicker and hum that many people associate with fluorescent bulbs. Note: Ballasts manufactured before 1978 may contain toxic polychlorinated biphenyls (PCBs). All ballasts manufactured after 1978 should have a "No PCBs" label.

Recommended Technique: Use fixtures that accept fluorescent bulbs.

The improved color performance and energy efficiencies of modern fluorescent bulbs make them an excellent choice for an energy efficient home. Table 15-B summarizes the general attributes of incandescent and fluorescent bulbs. See Table 15-C for a technical comparison of several types of incandescent and fluorescent bulbs. As previously discussed, those fluorescents that have a CCT of 3000 and a CRI of above 80 satisfy the criteria for color performance for most applications while providing excellent efficiency.

Table 15-B: General Comparison Incandescent vs. Fluorescent

Incandescent Bulbs	Fluorescent Bulbs
Short life of 2,000 hours maximum.	Long life of up to 20,000 hours.
Inefficient at about 10 to 15 lumens per watt.	Efficient at up to 90 lumens per watt, depending on size. Uses 75% less energy than a standard incandescent bulb.
Produce large amounts of heat.	Produce minimal amounts of heat because more watts are converted to light, less to heat (higher efficiency).
Good color quality.	Good color quality.
Expensive to operate.	Inexpensive to operate.
Low price per bulb.	High price per bulb; offset by operational savings. See Table 15-D. They are especially cost-effective in high use locations where lights will be on for long periods of time.
Available as screw-in units for standard fixtures.	Compact fluorescent bulbs (CFL) are available as standard screw-in units for fixtures. Beware of height and girth for table bulb applications; bulbshade harp may not fit over CFL; harp extenders are available.
Can be disposed, but not recycled.	Because most contain mercury, should not be disposed with regular garbage. Recycling options are increasing.

Table 15-C: Comparison of Various Incandescent and Fluorescent Bulbs.

Bulb Type	Watts	Lumens	Efficiency (Lum/W)	Average Bulb Life (hours)	Initial Cost	CRI	CCT (^{0}Kelvin)
Incandescent Soft White	100	1710	17.1	750	$0.30	95+	2800
Incandescent Double Life	90	1510	16.8	1500	$0.60	95+	2800
Incandescent Energy Saver	90	1510	16.8	750	$0.50	95+	2800
Incandescent Halogen A-Bulb	75	1040	13.9	2500	$5.94	95+	3050
Incandescent Halogen Flood, 50 Beam Spread	75	1100	14.7	2500	$6.24	95+	3050
Fluorescent, 48" Tube T12 Cool White	34	3050	89.7	20,000	$2.00	60+	4200
Fluorescent, 48" Tube T8 RE730	32	2850	89.1	20,000	$2.80	70+	3000
Fluorescent, 48" Tube T8 RE830	32	3050	89.7	20,000	$5.75	80+	3000
Compact Fluorescent, Lower Power	13	710	54.6	10,000	$15	80+	3000
Compact Fluorescent, Higher Power	27	1620	60	12,000	$21	80+	3000

SOURCE: Build Green & Profit. Advanced Concepts Participant Guide. University of Florida Extension Service, 1999. p13.

Note: Wattages for fluorescent tubes need to add a few watts for the ballast. Integrated screwbase CFLs will have the ballast watts already incorporated. Modular screwbase CFLs and other CFLs will also need ballast watts added.

Table 15-D (next page) provides a summary of several typical and energy-efficient lighting scenarios, and illustrates potential savings. Yearly costs were calculated using a $0.15 per kilowatt hour cost. Current utility rates on Oahu are $0.145 per kilowatt hour. Utility rates for the neighbor islands run as high as $0.22 per kilowatt hour, making for even more dramatic savings when applying the efficient scenarios.

Table 15-D: Typical and Efficient Residential Light Scenarios

Living Room Lighting Design	Kilowatt Hours (per year)	Yearly Cost at $0.15 per kWh
Typical: One ceiling fixture using two 60W incandescent bulbs for three hours a day. Two portable bulbs using one 75W incandescent bulb each for two hours per day.	241	$36.14
Efficient: Replace the 60W incandescent bulbs with 18W compact fluorescent bulbs. Replace the 75W incandescent bulb with a 24W compact fluorescent bulb.	74	$11.17
Kitchen Lighting Design		
Typical: One ceiling fixture in the center of the room using four T12 40W fluorescent bulbs for four hours a day. One ceiling fixture over the sink using one 60W incandescent bulb for two hours per day.	277	$41.61
Efficient: Replace the T12 bulbs with T8 bulbs. Replace the 60W incandescent bulb with an 18W compact fluorescent bulb.	200	$30.00
Bedroom Lighting Design		
Typical: One ceiling fixture in the center of the room using two 60W incandescent bulbs for three hours a day. Two table bulbs using one 60W incandescent bulb each for three hours a day. One portable bulb using one 75W incandescent bulb for three hours per day.	131	$19.71
Efficient: Replace the 60W incandescent bulbs with 18W compact fluorescent bulbs. Replace the 75W incandescent bulb with a 24W compact fluorescent bulb.	66	$9.86
Bathroom Lighting Design		
Typical: One ceiling fixture using one 60W incandescent bulb for two hours a day. One wall-mounted vanity fixture using three 60W incandescent bulb for two hours per day.	175	$26.28
Efficient: Replace all 60W incandescent bulbs with 18W compact fluorescent bulbs.	53	$7.88

Tips for selecting fluorescent bulbs and fixtures:

- For good color quality, choose fluorescent bulbs with a CRI above 80 and a CCT of 3000K.
- Use T8 or T5 fluorescent tubes, which are more efficient than the larger T12s.
- Look for the Energy Star® label on compact fluorescent bulbs and fixtures. Energy Star® is a USDOE/EPA Efficiency Rating Program. For more information about the program, see Appendix H.
- Choose low-mercury fluorescent tubes, such as Philips Alto, GE, or OSRAM-Sylvania bulbs, which are not classified as hazardous waste for disposal.
- Use electronic ballasts. They provide a higher efficiency and better quality of light.
- Use reflectors to direct light and increase the efficiency of bulbs.
- Use a single, higher-wattage bulb instead of several low-wattage bulbs. One high-wattage bulb will produce more light and use less energy than two small-wattage bulbs.

Recommended Technique: Conserve energy use for lighting with appropriate controls.

Controls such as switches, dimmers, timers, occupancy sensors, and photo sensors allow home owners to regulate lighting levels and use. Controls can be used to save energy and money and to change the "mood" of a room. They can also extend bulb life. When installing lighting controls, it is important to separate fan controls (such as bathroom and ceiling fans) from the lighting controls. This will ensure that lights are not activated when only the fan is desired.

As with fixtures, the best way to select the controls for a lighting system is to match them with the room's activities. Table 15-E presents a list of control types, their benefits, and appropriate uses.

Table 15-E: Lighting Control Types

Control Type	Benefits/Disadvantages	Application
Dimmers allow occupants to reduce lighting levels.	Saves energy, extends lamp life. Inexpensive method of creating intimate settings. Increases functionality.	Dining rooms, sitting areas, other rooms where low-level levels are sometimes desired.
Timers automatically turn lights on and off based on a programmed schedule.	Saves energy. Once set, doesn't depend on occupants remembering to turn lights off; however, because it is time-based, it may activate lights when not needed.	Living rooms, dining rooms, kitchen, bedrooms, or other rooms with regulated daily routines.
Motion sensors turn lights on when someone enters a room. After a period of inactivity, turns lights off.	Saves energy, because once set, doesn't depend on occupants remembering to turn lights off. Unfortunately because they're motion based, pets may activate lights when not needed.	Infrequently used areas, such as basement or storage areas.
Photo or light sensors turn lamps off when sufficient daylight is available and on when it is not. Daylight thresholds are preset.	Saves energy; usually more efficient than motion sensors because photo/light sensors are activated by light level.	Generally, photo sensors are used in large commercial applications such as office buildings. Most homes will benefit just by turning lights off when they are not needed.

Chapter 16: Appliances

Over the life of most household appliances, home owners will pay more money for the electricity to operate the appliances than it cost to purchase them. Energy-efficient appliances may cost more than standard appliances to purchase, but cost less to operate. Initial cost differences are made up in savings on monthly utility bills.

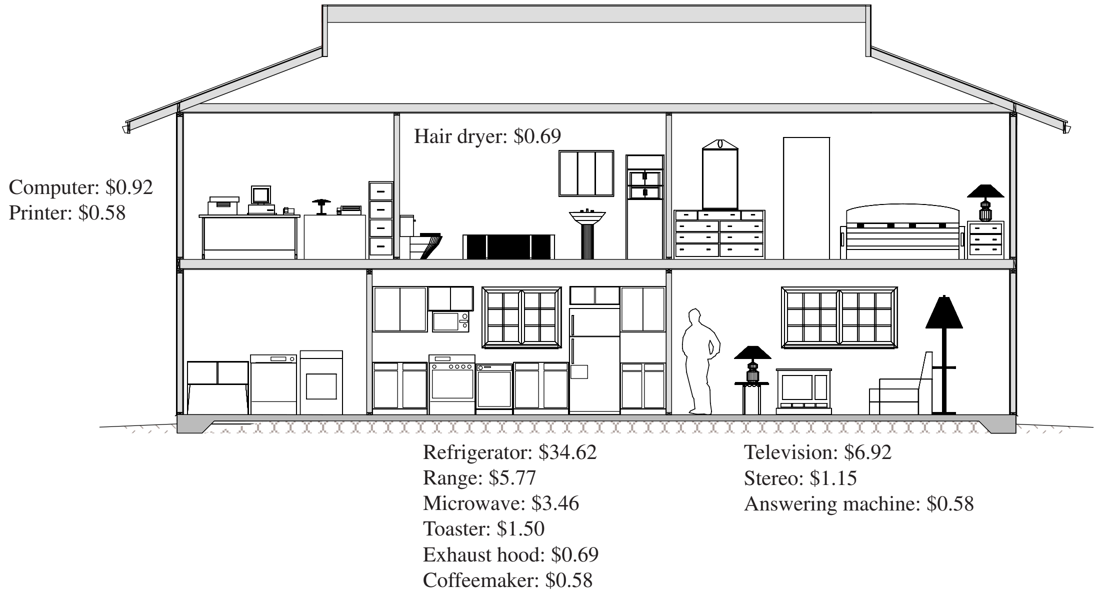


Fig. 16-1: Average Monthly Energy Costs for Common Household Appliances.
Note: Costs are based on a utility rate of 15 cents per kilowatt hour of electricity.

This Chapter focuses on one strategy: installing energy efficient household appliances. It provides tips for selecting energy efficient:

- Refrigerators
- Cooking appliances
- Laundry equipment
- Dishwashers

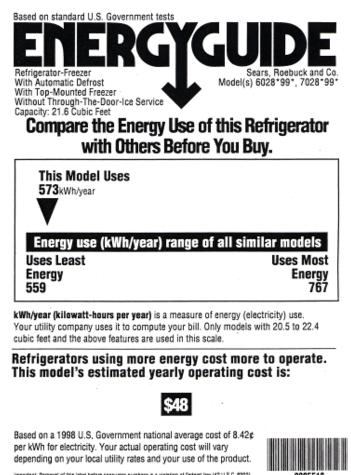


Fig. 16-2: Energy Guide Label.

To identify appliances with good energy performance, look for energy efficiency ratings (Energy Guide Labels) and Energy Star® and Green Seal compliance labels. Energy efficiency ratings can be found on the familiar yellow Energy Guide labels and show how the model compares to average energy use.

The ratings are not required for kitchen ranges, microwave ovens, or clothes dryers.

Appliances that carry Energy Star® or Green Seal labels exceed minimum energy use standards. These appliances are extremely efficient and will provide excellent payback in energy savings. For more information about the Energy Star® or Green Seal Label certifications, see Appendix H.

Recommended Technique: Select energy-efficient refrigerators.

In Hawaii, electrical demand for kitchen activities approaches 40% of the total energy consumed in the home. Refrigerators are the second biggest power consumer in most households and account for about 20% of electric bills of non-air conditioned homes. Home owners can achieve significant energy savings by purchasing an energy-efficient refrigerator.

Tips for selecting and installing energy-efficient refrigerators:

- Buy the right size model. Oversized units cost more to run. Undersized units will become overcrowded and use energy inefficiently. A unit of 14 to 17 cu. ft. is appropriate for three or four people. For each additional person in the household, add 2 cu. ft. The recommended sizes refer to the combined capacity of the refrigerator and freezer.
- Position the refrigerator away from heat sources such as stoves, ranges, and dishwashers.
- Models with overhead freezers are 10% to 25% more efficient than side-by-side models.
- Avoid models with ice makers and through-door water dispensers.
- Select models with separate temperature controls for the freezer and refrigerator compartments. This will reduce food spoilage and save energy.
- Provide ample air space (at least 3 inches) around refrigerator coils so they can operate efficiently.
- Select a unit with wheels to make it easier for home owners to move the refrigerator when it is time to vacuum the coils (twice a year).
- Set temperatures only as low as necessary (between 36° F and 38° F in the refrigerator, and between 0° F and 5° F in the freezer). A 10° decrease in temperature below these levels will increase energy use by 25%.

Recommended Technique: Select energy-efficient cooking appliances.

Cooking with electrical appliances accounts for about 10% of the home's overall energy demand. Ranges and ovens do not have Energy Guide labels, so it is important to look for the features listed below.

Tips for selecting and installing ranges and ovens:

- Install gas cook tops. Replacing an old electric range with a gas one can reduce cooking costs by 50% because cooking with gas is more efficient.
- Induction or halogen cook tops use less energy than conventional electric burners.
- Install hoods to vent heat and humidity from cooking.
- Use microwave and toaster ovens for reduced energy use.
- Install self-cleaning ovens. They have upgraded insulation and are more energy-efficient.
- Convection ovens perform better than conventional ovens. They cook more evenly and rapidly than non-convection types.
- Select an oven with a window. The cook can check on progress without opening the unit. Every time the oven is opened, as much as 20% of the heat escapes.

Recommended Technique: Select energy-efficient laundry equipment.

Modern energy-efficient clothes washers use about half the water of traditional machines and can reduce energy use by up to 65%.

An ideal combination is a front-loading horizontal axis clothes washer and a clothes line. A report done for the city of Portland, Oregon, estimates that a typical family can save about $120 each year using a horizontal axis clotheswasher and electric dryer. An H-axis washer saves energy because it uses one-third less water. This reduces the amount of energy required to heat the wash water (two-thirds less). In addition, an H-axis washer spins the clothes faster (and drier), reducing the amount of energy used by the clothes dryer.

H-axis washers offer other advantages over conventional, toploading machines, as well. They get clothes cleaner with less wear and tear on fabrics. They can also handle bulky items like comforters and rugs that top-loaders can't.

Laundry equipment produces heat and humidity and should be located in isolated non-air conditioned spaces. This will avoid increasing the home's cooling load.

Tips for selecting and installing laundry equipment:

- Choose an H-axis front loading clothes washer.
- Select a dryer with moisture sensors and cool down cycles.
- Vent clothes dryers directly to the outside of the building.
- Install a clothes line to cut heat and humidity generated by electric clothes dryers and save energy. Landscaping and fences can be used to screen clothes lines from view. If not permitted outdoors, install in a garage and provide ventilation.

Recommended Technique: Select energy-efficient dishwashers.

Like clothes washers, most of the energy used by dishwashers goes towards heating wash water. Look for dishwashers that require less water to do the job.

Tips for selecting and installing dishwashers:

- Install a washer with a built-in booster heater. The heater allows the homeowner to lower the temperature setting of the home's water heater while still having water hot enough to properly clean the dishes; every 10^0 F reduction in water heater temperature setting lowers energy consumption by 3% to 5%.
- Select a dishwasher that provides a "light wash" or "energy-saving" wash cycle.
- Look for a dishwasher that allows both heat-drying and air-drying. Air-drying uses less electricity.
- Select a dishwasher that is set up for easy cleaning of the filter at the bottom of the dishwasher. Regular cleaning will keep the machine running efficiently.
- Select a dishwasher equipped with a "Delay Search Start" feature. Home owners can use it to run the dishwasher during off-peak energy hours.
- Size the machine properly. Compact models use less energy, but hold fewer dishes. For larger households, a compact machine may end up using more energy because it may have to be run more often.

Chapter 17: Air Conditioning

Air conditioning a home can easily increase electricity costs by about $400 per year. In addition, air conditioning can produce an uncomfortable transition for those leaving or entering the air conditioned space due to significant differences in temperature and humidity. Thus, substantial energy savings over the life of the home and comfort are two excellent reasons to reduce or eliminate one's reliance on air conditioning. Perhaps an even more compelling reason is that there are few circumstances in Hawaii that warrant air conditioning. Hawaii's relatively stable and moderate weather provides a comfortable climate most of the year. (For more information on human comfort and Hawaii's climate, review Section I.)

The *Energy Efficiency Guidelines* strongly encourages well-designed, naturally ventilated energy-efficient homes (see Chapters 11 and 12). The *Guidelines* do, however, recognize special circumstances where air conditioning may be warranted, such as areas where microclimates require greater heat or humidity control, when occupants have special needs, or where existing conditions include environmental noise, dust, and pollution.

This Chapter introduces strategies for optimizing the energy use and comfort of air conditioned homes. Strategies include:

- Passive cooling strategies
- Sealing against energy "leaks"
- Energy-efficient air conditioning equipment
- Properly sized and designed air conditioning system

A note about codes: The *Guidelines* are voluntary and are not intended to substitute or replace existing jurisdictional construction requirements. Each county has its own code requirements for air conditioned homes. Refer to the code in your county before purchasing or installing an air conditioning system. Your home designer and building officials can help you identify energy-efficient strategies that are code compliant.

Three general types of air conditioning systems can be used for residential construction: window, split, and central. The system most appropriate for a particular home will depend upon the size, number, and type of spaces you wish to cool. Window units are ideal when you only need to cool a home office, for example. Central AC might be appropriate when the home is located near noisy air traffic or on a dusty highway.

Once an air conditioning system is installed, maintaining it properly is vital to ensure that the system performs efficiently. Maintenance tips for AC and other energy-using equipment are included in Appendix E.

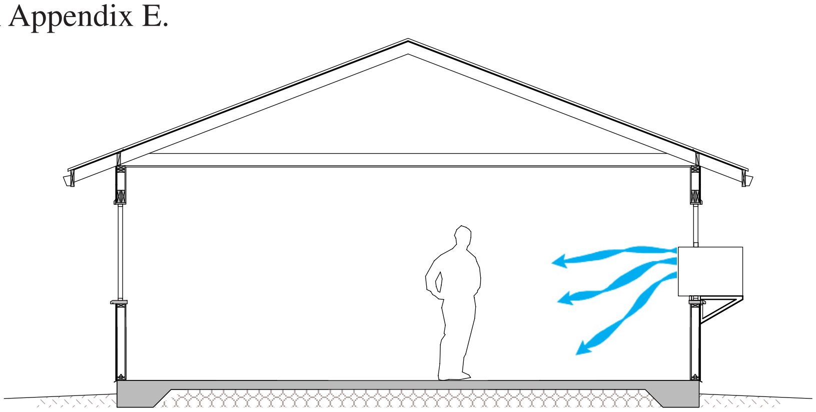


Fig. 17-1: Window AC Systems.

Window AC systems are factory assembled and encased in a single package. They are designed to cool one or two rooms without the use of ducts and are usually installed in a window or wall.

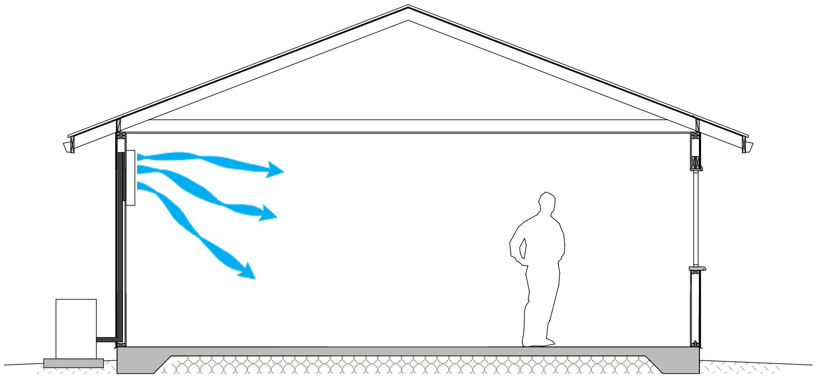


Fig. 17-2: Split AC Systems.

In *split AC systems,* the condenser and compressor are in one package outdoors, and the fan and cooling coils are located in wall or ceiling mounted units indoors. Chilled water lines run from the compressor unit outside to the fan unit inside. They can cool several rooms, are more efficient than window units, and are less noisy because the compressor is outside.

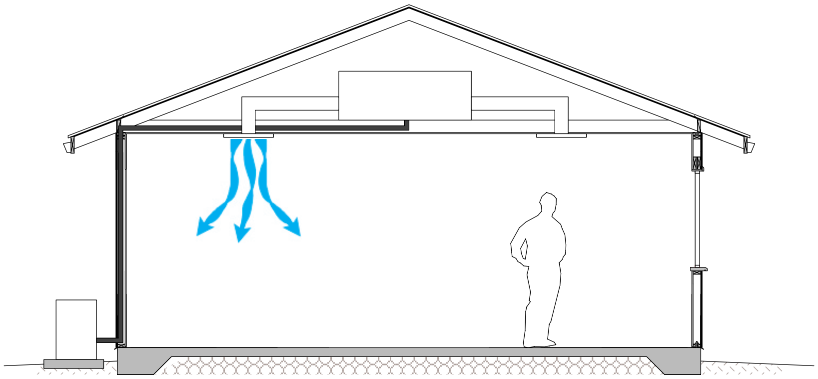


Fig. 17-3: Central AC Systems.

Central AC systems use factory-made components that are assembled by a contractor. They are designed to cool an entire house. A central unit delivers cool air to each room through ducts. Return vents circulate air in the house back to the unit where it is mixed with fresh air and recooled. Like split systems, they frequently have outdoor compressor/condenser packages linked to centrally located indoor air handlers by chilled water circulation lines.

Recommended Technique: Employ passive cooling strategies to reduce cooling load.

Even when a home is air conditioned, use passive cooling strategies that reduce heat build up such as insulation, radiant barriers, shading, ceiling fans, and operable windows. By keeping the home cooler, insulation, radiant barriers, and shading reduce the amount of air conditioning needed. Operable windows permit the use of natural ventilation on cool days. Ceiling fans can improve airflow with natural ventilation or allow for comfort with higher AC thermostat settings. Together, these strategies can reduce the amount of energy required to run an AC system by 20% to 50%.

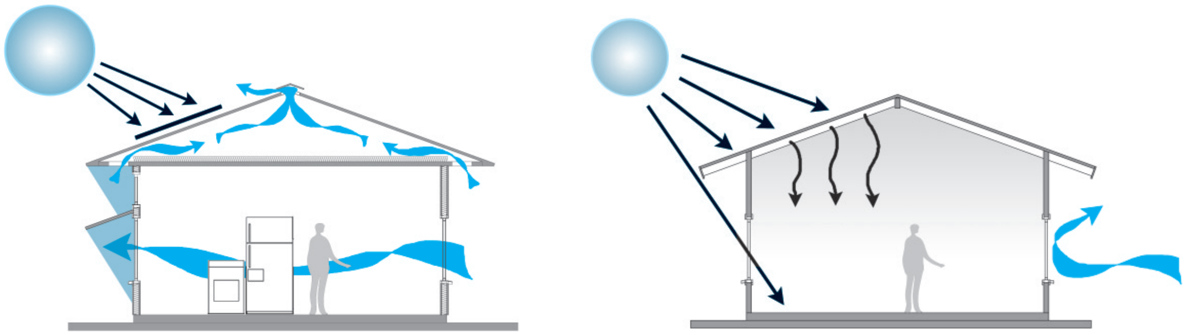


Fig. 17-4: Passive Cooling Strategies.
A house with proper insulation, operable windows, and radiant barriers will require a much smaller air conditioning system compared to a “conventional” home. An AC system in the same house without these passive cooling strategies will cost more to operate, especially during the hot summer months.

Recommended Technique: Seal the building envelope against energy leaks.

Once you have incorporated insulation, radiant barriers, and shading in your design, the next step is to prevent cooled air from leaving and warm air and humidity from entering the home. Such energy "leaks" are inexpensive to prevent but very expensive to ignore. Air leaks waste energy and reduce comfort levels in the home by letting cold air out, and allowing warm humid air in.

Use high-quality caulking products and plug all potential leaks at door and window openings, joints, cracks, and holes in and between walls, ceilings, and floors. Although higher-quality products such as acrylic latex, polyurethane, or silicone-based sealants cost more than PVC or oil-based materials, they last five times longer. Plus, the upgrade cost is minimal relative to the overall cost of construction.

Look for caulking products that have the Green Seal label. Green Seal rates caulking products based on durability, ease of clean up, VOC level, and hazardous materials. Check their recommended product list online at www.greenseal.org. See Appendix H for more information about the Green Seal program.

Important Note: Indoor Air Quality in Tightly Sealed Air-Conditioned Homes

In energy-efficient air conditioned homes, windows, doors, and other openings are sealed to prevent the loss of cool air. This also prevents fresh air from entering the house. Without an alternative source of fresh air, high levels of contaminants including mold, fungi, carbon monoxide, and *volatile organic compounds* (VOCs) can build up. (VOCs are responsible for the troublesome odors associated with the installation of new carpet, paint, and other building products.)

It is important to ensure the AC system brings in a generous supply of fresh air. In addition, AC systems must be properly maintained to avoid introduction of contaminants. Installation allowing for easy maintenance is therefore key. These issues are discussed later in this chapter.

For further discussion of Indoor Air Quality issues within the home see resources listed in Appendix B.

Recommended Technique: Design windows for use in air conditioned spaces.

Use double-pane insulating windows that are designed for use in air conditioned spaces to maintain comfort while saving energy and money. For more information on windows and glazing see Chapter 10. Windows that cannot be tightly sealed, such as jalousies, should not be used in conditioned spaces. If they are necessary, limit them to 2% of floor area, or choose cam-locking types that can be tightly closed.

Recommended Technique: Select systems with a Seasonal Energy Efficiency Ratio (SEER) of 12 or higher.

Air conditioners are rated by their *Seasonal Energy Efficiency Ratio (SEER)*. The SEER indicates an air conditioner's efficiency by measuring cooling output divided by electrical energy input. It is expressed in British thermal units per watt-hours (Btu/Wh). The higher the SEER, the more efficient the unit. High SEER models generally cost more than lower-efficiency models, but this initial cost is offset by lower utility bills. Some units have SEER ratings as high as 17.

Recommended Technique: Properly size AC unit(s).

Proper sizing is critical for air conditioner efficiency. Many people buy large air conditioners, thinking they will do a better job. This is not the case. An oversized air conditioner will actually be less effective at cooling a home than one that is the correct size. An oversized system will cost more to install, waste energy, increase your electric bill, and potentially create moisture and indoor air quality problems.

Air conditioners work by removing heat and humidity from the air. Humidity is removed when air passes over the cooling coils of an air conditioner. If the unit is too large it will cool the air quickly and then shut off. Unfortunately, short-run cycles like this keep the air conditioner from effectively removing humidity. In effect, an oversized unit will cool a room quickly, but only remove a portion of the humidity. This will leave the room with a damp, clammy feeling and can also lead to mold and mildew problems. A properly sized unit will remove humidity effectively as it cools. Use Table 18-A to estimate the appropriate size air conditioner for your application.

Table 18-A: Matching Area to AC Capacity

Area to be Cooled (sq. ft.)	Capacity (Btu/hr)
100 to 150	5,000
150 to 250	6,000
250 to 300	7,000
300 to 350	8,000
350 to 400	9,000
400 to 450	10,000
450 to 550	12,000
550 to 700	14,000
700 to 1000	18,000

Adjust the estimated size if any of the following apply:

- If the room is heavily shaded, reduce capacity by 10%.
- If the room is very sunny, increase capacity by 10%.
- If more than two people regularly occupy the room, add 600 Btu/Hr for each additional person.
- If the unit is for a kitchen, increase the capacity by 4,000 Btu/Hr.

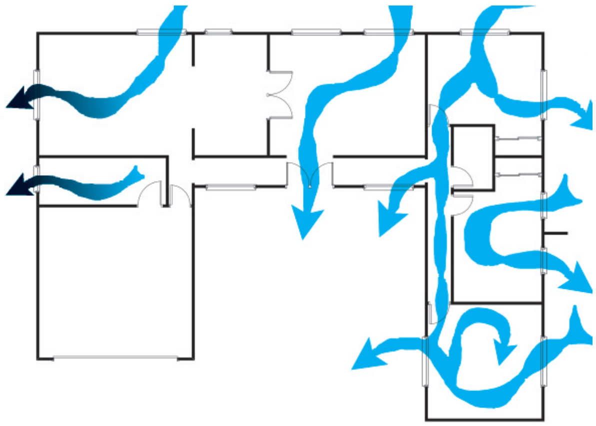
Source: www.energystar.gov

Recommended Technique: Zone and control the AC system.

Various areas, or zones, within the home have different cooling needs due to differing activities and thermal exposures. For example, the cooling requirements for a bedroom on the north side of a house would be very different from those of a busy kitchen with a wide western exposure. Separate controls for each zone increase the efficiency of the overall system, which increases comfort and decreases operating costs.

Recommended Technique: Ensure AC system provides a generous supply of fresh air.

When air conditioning is used, it is important that the system provide adequate fresh air. The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has set a guideline for home ventilation of 0.35 air changes per hour (ACH). One air change is the volume of fresh outside air needed to replace all of the air inside a house. An ACH of 0.35 means that about one-third of the air in a house is replaced with fresh air every hour. Ventilation for air handling systems can also be measured in cubic feet per minute (CFM). A rule of thumb often used for ventilation in a home is 15 CFM of fresh air per person. To estimate the amount of fresh air needed to provide adequate ventilation, calculate using both methods and use the larger result. See example below.



- Method 1 (Rule of Thumb): Number of persons: 4 x 15 CFM = 60 CFM.
- Method 2 (ASHRAE ACH): 1,800 sq.ft. x 8' ceiling = 14,400 cubic feet. 14,400/60 x 0.35 = 84 CFM

Fig. 17-5: Estimating Fresh Air Requirements for Air Conditioned Homes.

In this three-bedroom 1,800 square foot house with 8-foot ceilings and four occupants, the ASHRAE method gives the higher result and recommends 84 CFM of fresh air.

Recommended Technique: In central air conditioned homes, ensure balanced airflow.

A centrally air conditioned home usually has supply vents in every room and often only one return air vent. If the doors to one or more rooms are shut, the air being supplied to those rooms will not be recirculated by the AC system. The return vent will be "starved" for air, which will cause the room with the return vent to become under pressurized. The closed rooms will become over-pressurized, forcing air out through any leaks in the building envelope. In this way, an air conditioning system can become unbalanced and allow air infiltration, which will result in wasted energy and money.

Door cuts (increasing the gap at the bottom of the door) are often used as a method to balance pressure between rooms. This is not a reliable practice. Instead, install return vents in every room with an air supply or install transfer registers in uninsulated interior walls to allow the pressure between rooms to equalize. Figure 17-6 illustrates a transfer grille.

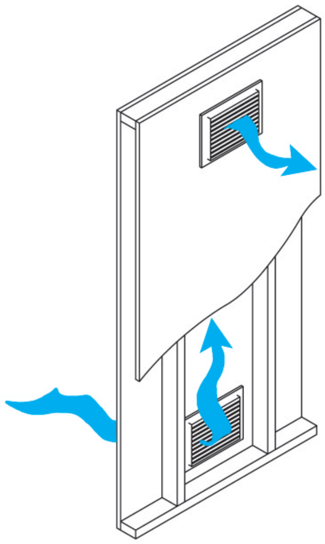


Fig. 17-6: Ensuring Balanced Air Flow.

Transfer grilles can prevent rooms with supply vents from being over-pressurized.

Recommended Technique: When installing a central air conditioner, seal ducts to avoid leaks.

A survey by the Florida Solar Energy Center found that the average home in Florida lost 11% of its cooling energy because of poorly sealed ductwork. After the duct systems of those homes were repaired, their annual heating and cooling bills were reduced by an average of $110.

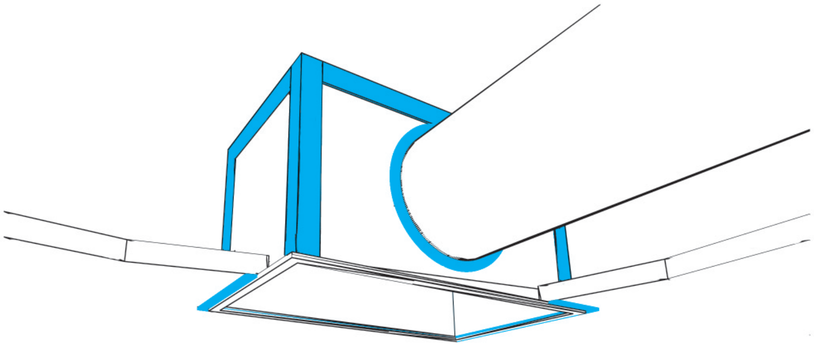


Fig. 17-7: Air Sealing of Ductwork.

Leaky ductwork can contribute up to 60% of the air leakage in a home. If ducts are insulated with fiberglass, sealing will also prevent these fibers from entering the air stream, which creates a health hazard. Sealing will also protect moisture buildup, which fosters the growth of mold and mildew, another health hazard.

Tips for optimizing ductwork performance:

- Properly seal ducts using a "mastic" (adhesive paste). Duct tape can deteriorate quickly and should not be used to seal ducts. If a gap is larger than .25 inch, reinforce the mastic with a fiberglass mesh tape. Note: Lawrence Berkeley National Laboratories is developing a new sealing technology using an aerosol spray.
- Install galvanized ducts. The zinc coating will deter mold growth.
- Insulate the ducts to R-11 or above. Or install them in conditioned spaces to keep them in the same temperature range as the spaces to which they are supplying conditioned air. An un-insulated duct in a hot attic will lose energy across the duct wall through conduction. Ducts can lose about the same amount of energy through conduction as they can through leaks.
- Avoid flexible ducts whenever possible. Their corrugated surface resists airflow and forces the AC system to work harder.

Recommended Technique: When installing window units, optimize performance.

Here are some guidelines to follow when installing window units:

- Install window air conditioners on a level surface so that the drainage system and other mechanisms operate efficiently.
- If possible, install the unit in a shaded spot on the home's north side. Direct sunlight on the unit's heat exchanger decreases efficiency.
- Use plantings or shading devices to shade the air conditioner, but do not block the airflow. A unit operating in the shade uses as much as 10% less electricity than the same one operating in direct sunlight.

Recommended Technique: Install the AC system so it can be easily maintained.

A poorly maintained AC system will waste energy, have higher repair costs, and could lead to mold and mildew problems. With regular maintenance, an air conditioner can retain up to 95% of its efficiency. If not properly maintained, an air conditioner can lose 5% of its operating efficiency every year. This means that without regular maintenance an AC unit with a SEER of 12 could actually be operating with a SEER of 9 after just a few years. Builders should refer owners to the AC maintenance tips in Appendix E.

Summary of Key Strategies and Recommended Techniques for Section III

Water heating:
- Install solar water heating.
- Install water-conserving fixtures and appliances.
- Properly size water heating equipment.
- Select high performance hot water heating equipment.
- Practice efficient operation and maintenance.

Daylighting:
- Minimize difficult-to-shade east- and west-facing windows.
- Design interior layouts to match lighting needs to daylight availability.
- Use light-colored interior finishes effectively.
- Design floor plans to allow deep daylight penetration.
- Use light shelves when sidelighting.
- Rely on clerestories or roof monitors for toplighting.
- Prevent heat gain and glare when installing skylights.

Electric lighting:
- Design for effective electric light delivery.
- Use fixtures that accept fluorescent bulbs.
- Conserve energy use for lighting with appropriate controls.

Appliances:
- Select energy-efficient refrigerators.
- Select energy-efficient cooking appliances.
- Select energy-efficient laundry equipment.
- Select energy-efficient dishwashers.
- Select systems with a seasonal energy efficiency ratio (SEER) of 12 or higher.

Air conditioning:
- Use air conditioning only when absolutely necessary.
- Employ passive cooling strategies to reduce cooling load.
- Seal the building envelope against energy leaks.
- Select AC systems with a Seasonal Energy Efficiency Ratio (SEER) of 12 or higher.
- Properly size the AC system.
- Zone and control the AC system.
- Ensure AC system provides a generous supply of fresh air.
- In central AC homes, ensure balanced airflow.
- When installing central AC, seal ducts to avoid leaks.
- When installing window units, optimize performance.
- Install the AC system so it can easily be maintained.